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(54) Gas turbine engine combuster

(57) A lean burn combustor (100) for a gas turbine engine has a combustor head (103) and a combustor wall (104) which defines a combustion volume (105) supporting a lean burn combustion process. A divergent flame front (106) of the combustion process expands into the combustion volume (105) from the head (103) of the combustor and approaches the combustor wall (104), which is pierced by a band (107) of small holes (113) for low-rate flow of air from outside of the combustor wall onto the inner surface (119) of the wall. The band (107) of small holes is located in a region of the wall adjacent the divergent flame front (106) of the lean burn combustion process and exerts a damping effect on high frequency combustion vibrations propagated in and from the flame front.

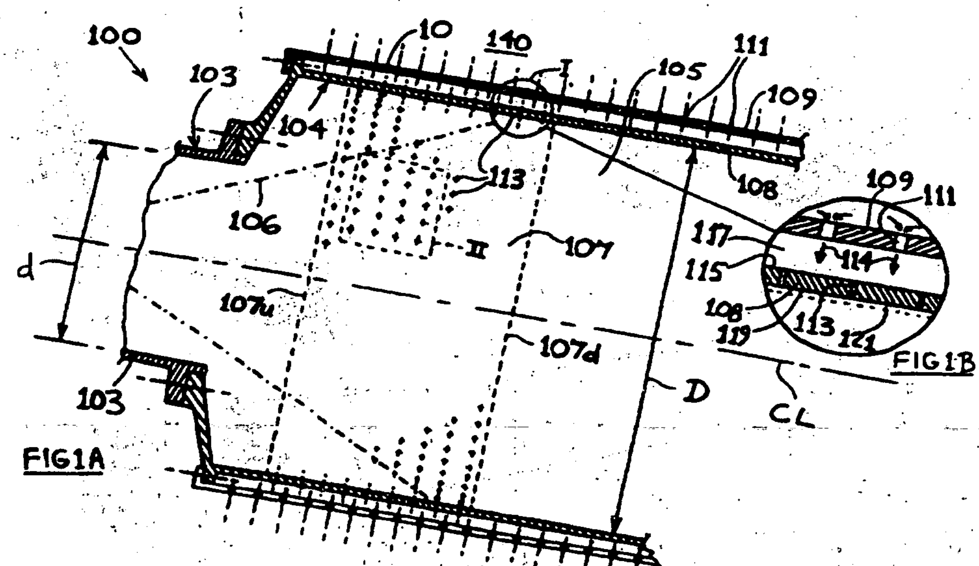

FIG1A

FIG1B

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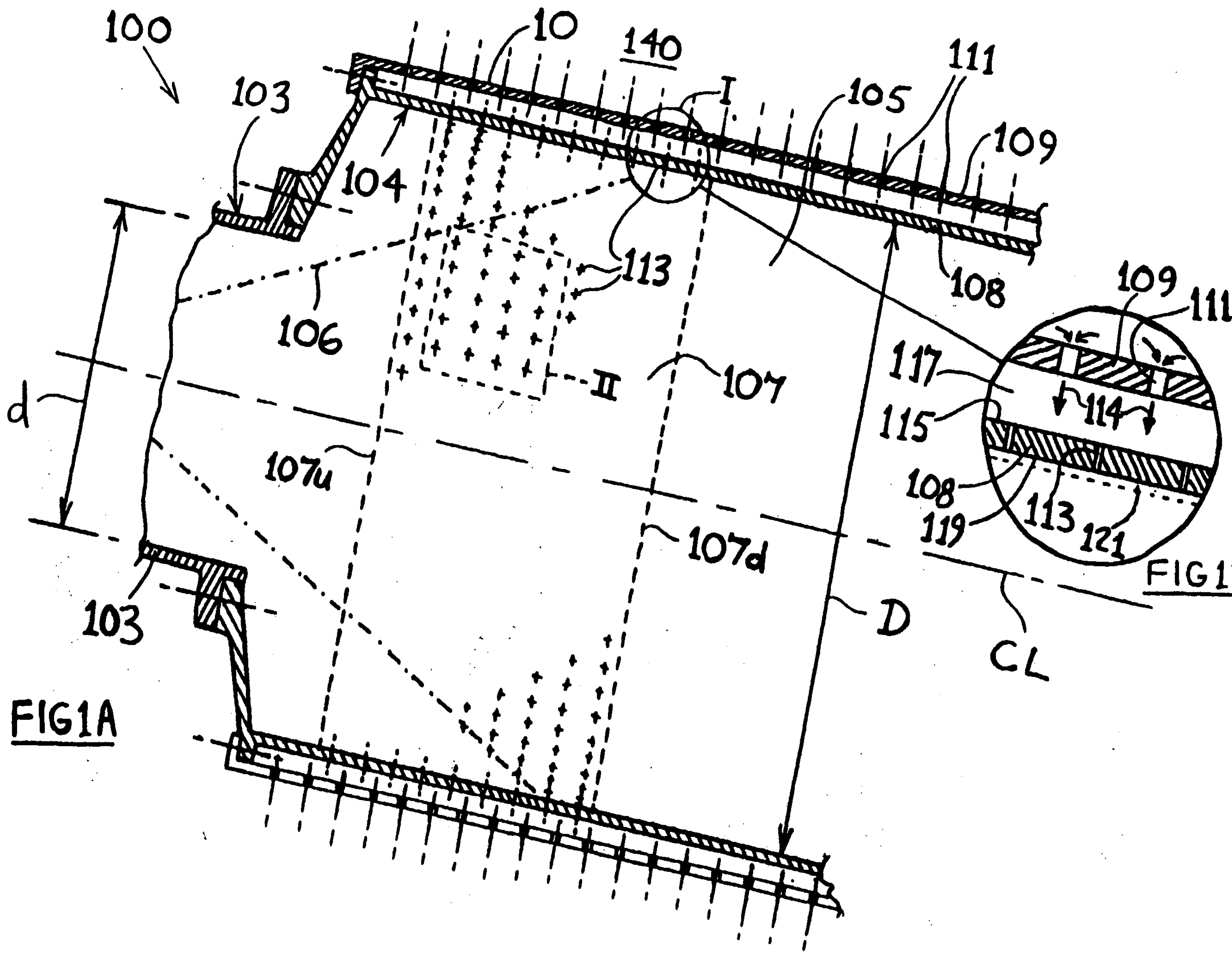
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FIG1A

FIG1B

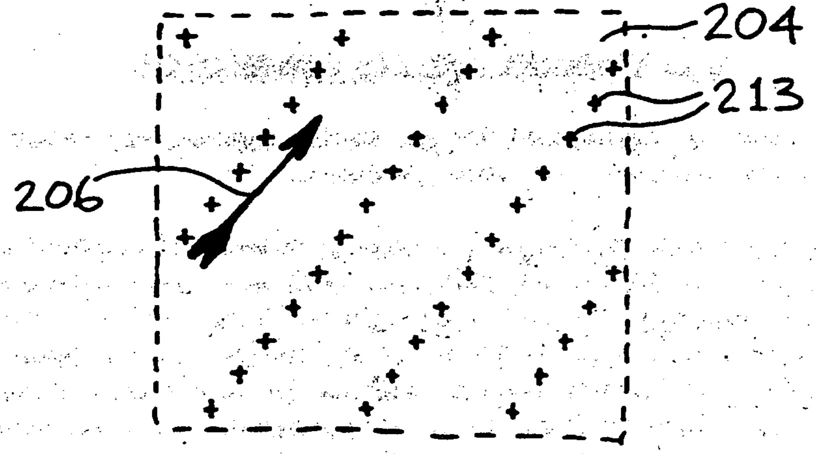

FIG. 2

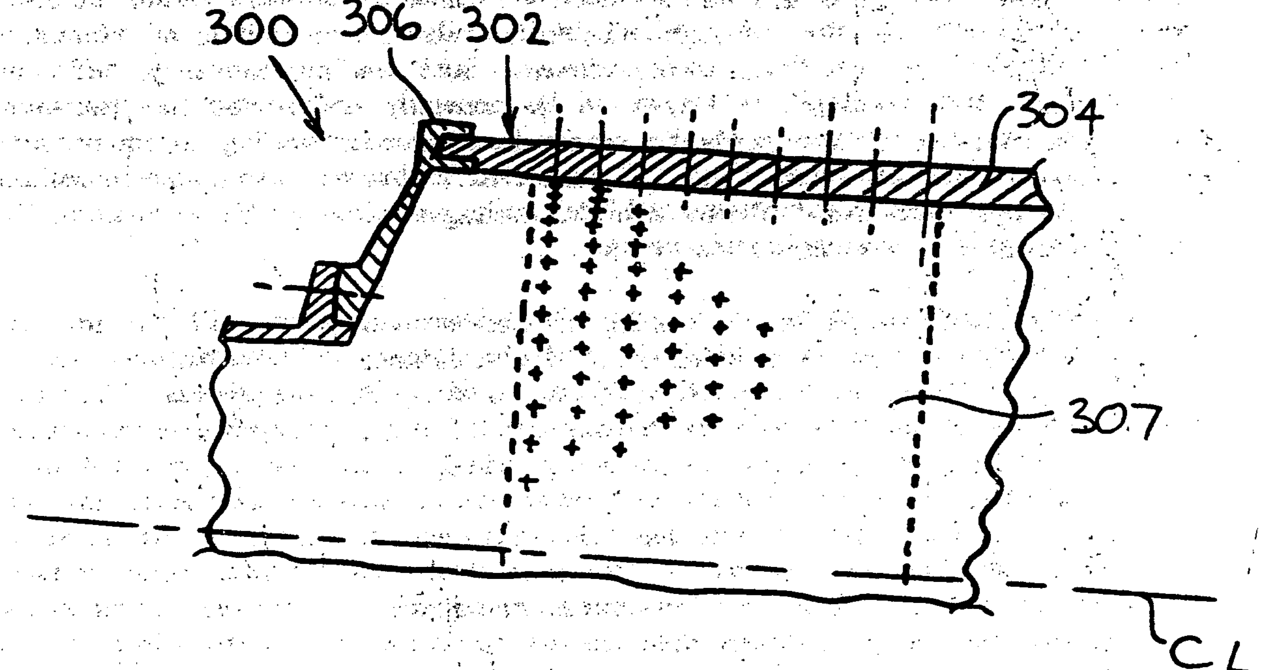

FIG. 3

GAS TURBINE ENGINE COMBUSTOR

This invention relates to combustors for gas turbine engines, particularly combustors suitable for sustaining lean burn combustion processes..

A known type of combustor is designed to support "lean-burn" combustion in order to minimise production of environmental pollutants, such as the various oxides of nitrogen ("NOx"), carbon monoxide ("CO") and unburnt hydrocarbons ("UHC's"). In combustors of the lean-burn type, sufficient air for stoichiometric combustion is mixed with the fuel before combustion begins, whereas for combustors utilising fuel-rich fuel/air mixtures, i.e., diffusion-flame types of combustion processes, some of the air necessary to achieve stoichiometric combustion is introduced into the combustion process after it has begun.

It is considered detrimental to the lean-burn process to introduce much air into the combustor at locations downstream of the region in the combustor where the combustion process is initiated. However, inability to put cool air into the downstream parts of a lean burn combustor causes a problem with respect to providing adequate cooling of metallic combustor walls. In known "rich-burn" combustors, metallic walls, optionally provided with insulating ceramic coatings, can be adequately cooled by allowing cooling air from outside the combustor to flow through holes in the walls to form cooling and protective layers or films of air over their inside surfaces. Such cooling, known as "effusion cooling" and "film cooling", is known to be generally undesirable for lean-burn combustors because it over-cools the combustion process, leading to incomplete combustion and excessive production of CO and UHC's. For this reason, known designs of lean-burn combustor avoid effusion and film cooling as techniques for maintaining the combustor walls at a serviceable temperature.

An alternative arrangement for air cooling of lean-burn combustor walls provides the combustor with inner and outer skins (i.e., a double-skinned wall construction) over at least a part of its length most exposed to the heat of the combustion process. The inner skin is without any apertures or holes for the entry of air into the combustor before the fuel has been completely consumed, although plunge holes may be provided in a downstream part of the combustor for the introduction of air after combustion has been completed. However, the outer skin has holes in it which are effective to direct jets of cooling air onto the outer surface of the inner skin, this technique being termed "impingement cooling". Such double-skinned impingement cooled wall constructions may be made in any type of metallic, ceramic or composite material which is not sufficiently heat resistant to be used without cooling in the combustor environment.

A further problem with lean-burn combustors is that compared with rich-burn combustors, they have higher airflows entering the upstream (i.e., "head") regions of the combustors. This can result in disturbances in the combustion process, leading to high

frequency combustion vibrations or oscillations. These combustion vibrations propagate in the divergent flame front of the combustion process as it expands into the combustion volume from the head of the combustor and approaches or meets the combustor wall. The vibrations impinge on the combustor wall and, on occasion, can be of such magnitude that premature failure of combustor components becomes a serious problem.

It is therefore an object of the invention to facilitate the reduction of such combustion vibrations in lean-burn combustors for gas turbine engines. The invention achieves this by modifying the combustor wall so that it has a damping effect on the combustion vibrations. The modification to the combustor wall is surprising, in that it introduces additional air into the lean burn combustion process downstream of its initiation, but upstream of its completion. However, the introduction of the air is such as to avoid quenching of the combustion process.

According to the present invention, a gas turbine engine combustor has a combustor head and a combustor wall defining a combustion volume for supporting a lean burn combustion process, in which a divergent flame front of the combustion process expands into the combustion volume from the head of the combustor and approaches the combustor wall, the wall having a band of small holes therethrough for a low-rate flow of air from outside of the combustor wall onto the inner surface of the wall, the band of small holes being located in a region of the wall adjacent the divergent flame front of the lean burn combustion process, whereby the combustor wall exerts a damping effect on high frequency combustion vibrations.

In an exemplary embodiment of the invention, the combustor wall has a double skinned metallic construction over at least part of its extent, the double skinned wall construction comprising an inner skin and an outer skin, the outer skin having apertures therethrough for effecting impingement cooling of the outer surface of the inner skin, and the inner skin having the band of small holes therethrough to obtain the vibration damping effect. Preferably, the small holes in the inner skin are not larger than about one-third the size of the holes in the outer skin.

In an alternative exemplary embodiment of the invention, the combustor wall has a single skinned ceramic construction over at least part of its extent, the single skin having the band of small holes therethrough.

The band of small holes should be confined to a region of the wall nearest the divergent flame front of the lean burn combustion process during a predetermined troublesome engine condition or range of engine conditions.

To avoid quenching of the lean burn combustion process with excess cool air from outside the combustor, it is important that the number of holes in the band of small holes,

and the flow of air through them, is the minimum necessary to achieve the required high frequency damping effect.

In cases where combustion gases in the divergent flame front have a swirl (i.e., rotational) component of motion and the combustion gases have a resultant spiral motion longitudinally of the combustor, the band of small holes may be arranged in a spiral pattern which approximates to the spiral motion of the combustion gases, thereby to minimise mixing of the combustion gases with the air from the small holes.

Exemplary embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1A is a part sectional diagrammatic side elevation of part of a lean burn combustor can incorporating a combustor wall in accordance with the present invention;

Figure 1B is an enlargement of the circular area I in Figure 1A;

Figure 2 is an enlarged view of an area like that of area II in Figure 1, but showing an alternative hole pattern in the combustor wall;

Figure 3 is a broken-away view similar to part of Figure 1, but showing an alternative form of combustor wall.

Referring to Figures 1A and 1B, a cylindrical combustor can 100 in a combustor section of a gas turbine engine is one of several such cans arranged around the circumference of the engine. Each can 100 has a combustor wall 104 with a relatively large internal diameter D extending for most of the can's axial length as measured along its longitudinal axis or centreline CL, but at its upstream or head end 103 the can has a short length of wall with a smaller internal diameter d. Although described with reference to this generally cylindrical type of combustor can, the invention should not be restricted to such, and is also applicable to annular types of combustor.

Each can 100 is provided with a fuel injector or burner assembly (not shown) in its head 103. If details of an example of such an assembly are required, our copending patent application GB9519826.3, or subsequently filed application(s) claiming priority therefrom, should be consulted. The combustor wall 104 defines a combustion volume 105 for supporting a lean burn combustion process. In operation, a fuel/air mixture from the burner assembly is introduced into the combustor head 103 and combustion is initiated there, for example, as shown and described in the above-mentioned copending application. A divergent flame front of the combustion process, approximately indicated by the chain-dotted line 106, expands into the combustion volume 105 from the head of the combustor, the flame front 106 being of generally frustoconical form and symmetrical about the can's centreline CL. Combustion continues in the combustion volume 105 downstream of the flame front.

In Figure 1A, the portion of combustor wall 104 shown has a double skinned metallic construction, comprising an inner skin 108 and an outer skin 109. As best seen in Figure 1B, the outer skin is pierced with holes 111 around its circumference over at least the portion of its length illustrated in Figure 1A, which encloses the hottest part of the combustion process, and the inner skin 108 is pierced by a circumferentially and axially extending band 107 of smaller holes 113. The band 107 is shown as defined between upstream and downstream dashed lines 107u, 107d, respectively, and is in a region of the combustor wall which is well upstream of the region of the combustor volume 105 where the fuel has been completely burnt.

Holes 111 are sufficiently large and sufficiently close together to perform effective impingement cooling of the inner skin 108 by directing air jets 114 onto its outer surface 115, in known manner. Such air jets are formed because the space 140 surrounding the combustor can 100 is pressurised by air bled from a compressor (not shown) of the gas turbine engine, most of the air from the annulus 117 between the inner and outer skins 108,109 being exhausted through the annulus to a region of lower pressure (not shown) in the engine, downstream of the combustor.

On the other hand, holes 113 in inner skin 108 are sufficiently small and sufficiently widely spaced to allow air to flow through the holes only relatively slowly from its outer surface 115 onto its inner surface 119. Relative to the effusive flow of air 114 through holes 111 in the outer skin 109, the flow of air through the smaller holes 113 in the inner skin 108 must be at a lower rate which avoids quenching of the lean burn combustion process with excess cool air from outside the combustor.

As previously explained, the large airflows entering the head region 103 of the combustor 100 can result in disturbances in the combustion gases, leading to high frequency vibrations or oscillations in the combustion process at some engine operating conditions. These high frequency combustion vibrations propagate in the divergent flame front 106 as it expands from the combustor head 103 into the combustion volume 105, and impinge on the inner skin 108 of the combustor wall 104. It is found that the presence of the small holes 113 in the inner skin 108 of the combustor wall 104 exerts a damping effect on high frequency combustion vibrations emanating from the flame front 106. One explanation of this effect, to which the applicants do not want to be held, is that the holes 113 can function similarly to holes in an acoustic lining, to absorb some of the high frequency noise falling on them. Alternatively, or additionally, it may be that the air which flows relatively slowly through the holes 113 acts to thicken the boundary layer 121 of gases adjacent the inner surface 119 of the combustor wall, so in effect providing an air cushion having a damping influence on the dynamics of the flame front.

In designs according to the invention, Applicants found that the holes 113 in the inner skin 108 function satisfactorily, without deleteriously affecting the lean-burn combustion process, if they are not more than about one-third the size of the holes in the outer skin,

the band 107 having a hole density of about 1500 holes per square meter. For instance, hole sizes of 0.7 to one millimeter have been employed in the inner skin to successfully damp combustion vibrations in the frequency range 3 to 9 KHz.

As engine conditions vary from start-up through part load to full load, the exact location at which the flame front meets, or most closely approaches, the combustor wall 104 will vary axially of the combustor. Therefore, the axial position of the damping holes 113 on the combustor wall 104 is important. In arrangements according to the invention, the band of small holes 113 should be near the flame front 106 during an engine condition or range of engine conditions which is troublesome with respect to the high frequency combustion vibrations. For example, to be effective over a troublesome range of engine powers, the band 107 is positioned so that at the high end of the range, the outer end of flame front 106 will be at or near to the downstream side 107d of band 107, while at the low end of the range, the flame front will move somewhat nearer the upstream side 107u.

As already implied, to avoid degradation of the lean burn combustion process, the number of small holes 113 in the band 107 should be the minimum necessary to achieve the high frequency damping effect required by the invention. This design trade-off may be easier to achieve in some designs of combustors than in others. For instance, in some combustors, it may be that high frequency combustion vibrations only become a problem at one engine condition, and in this case, the width of the band 107 can be correspondingly narrower, containing correspondingly fewer holes, since it does not have to accommodate a range of movement of the flame front 106.

For reasons explained in our copending patent application GB9519826.3, it is much preferred, though probably not essential in every design of combustion chamber and burners based on the invention disclosed therein, that the combustion gases in the divergent flame front 106 have a swirl (i.e., rotational) component of motion about the longitudinal axis CL of the combustor. The combustion gases have a resultant spiral motion around the axis CL. In such cases, it may be advantageous if, as shown in Figure 2, the damping holes 213 in the combustor wall 204 are arranged in a spiral pattern which approximates to the spiral motion of the combustion gases in the flame front as it meets the combustor wall. The direction of spiral motion in the flame front relative to the combustor wall is indicated by the arrow 206 and rows of damping holes 213 are aligned with this. The spiral arrangement may be effective to minimise mixing of the combustion gases with the air exiting from the damping holes 213, which in turn should minimise any quenching effect on the combustion process.

In Figure 3, the double skinned wall construction shown in Figures 1A and 1B has been replaced by a single skinned wall 302 over at least part of the axial extent of the large diameter portion of the combustor 300. Combustor wall 302 comprises a cylinder 304 of a refractory ceramic material, which is held in position by flanged refractory metal portions of the combustor, such as item 306. Like the combustor wall 104 in Figure 1,

the ceramic cylinder 304 is provided with a band 307 of small holes 313 which penetrate its thickness to allow for a low-rate flow of air through them to provide the damping effect on combustion vibrations.

It will be appreciated by those skilled in the art that for each particular design of combustor, it will be necessary to find an axial position for the band of combustion vibration damping holes in the combustor wall, a size for the holes, and their number per square meter, which are effective to damp the combustion vibrations without quenching the combustion process. This can be accomplished by experiments, using the information given herein.

CLAIMS

1. A gas turbine engine combustor having a combustor head and a combustor wall defining a combustion volume for supporting a lean burn combustion process, in which a divergent flame front of the combustion process expands into the combustion volume from the head of the combustor and approaches the combustor wall, the wall having a band of small holes therethrough for a low-rate flow of air from outside of the combustor wall onto the inner surface of the wall, the band of small holes being located in a region of the wall adjacent the divergent flame front of the lean burn combustion process, whereby the combustor wall exerts a damping effect on high frequency combustion vibrations.

2. A combustor according to claim 1, in which the combustor wall has a double skinned construction over at least part of its extent, the double skinned wall construction comprising an inner skin and an outer skin, the outer skin having apertures therethrough for effecting impingement cooling of the outer surface of the inner skin, and the inner skin having the band of small holes therethrough.

3. A combustor according to claim 1, in which the combustor wall has a single skinned ceramic construction over at least part of its extent, the single skin having the band of small holes therethrough.

4. A combustor according to any preceding claim, in which the band of small holes is confined to a region of the wall near the divergent flame front of the lean burn combustion process during a predetermined troublesome engine condition or range of engine conditions, the number of holes in the band being the minimum necessary to achieve the required high frequency damping effect, thereby to avoid quenching of the lean burn combustion process.

5. A combustor according to any preceding claim, in which the band of small holes are arranged in a spiral pattern approximating to a spiral motion of the combustion gases.

6. A gas turbine engine combustor substantially as described herein, with reference to the accompanying drawings.

8

Patents Act 1977 **..aminer's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9520778.3
Relevant Technical Fields (i) UK Cl (Ed.N) F4T (TAR3, TAR4, TAR5) (ii) Int Cl (Ed.6) F23R 3/06 3/42	Search Examiner R F PHAROAH Date of completion of Search 19 DECEMBER 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1-6

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2206686 A	(G.E.C.) see page 10, line 6 - page 12, line 11	1, 2
X	GB 2169696 A	(G.E.C.) see page 3, line 68 - page 4, line 17	1, 2
X	GB 0816878 A	(ROLLS-ROYCE) see page 2, line 53	1

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